CASE STUDY

Sarakasi Theatre
Nairobi, Kenya
Room Acoustical Measurements and Modelling

Africa
Room Acoustics
DIRAC and ODEON

In November 2008, room acoustical measurements were performed inside the Sarakasi Theatre in Nairobi using an ultra lightweight travelling measurement set. The nearby market in the slums was also visited in search for affordable and available acoustical materials. By using an improvised measurement setup, the sound absorption of materials was measured and used in room acoustical prediction modelling.

***Fig. 1** In the Sarakasi Theatre, youth from the city slums are trained to be acrobats and musicians. The performance below is from the recent Sawa Sawa Festival which took place at the theatre*

Photographs by kind permission of Marion van Dijck

Measuring Reverberation Time and Speech Intelligibility using Balloons and an MP3 Player as External Sound Sources

The non-profit organisation Sarakasi Trust owns a theatre in Nairobi Kenya, inside the former Shan Cinema. In this theatre, youths from the city slums are trained to be acrobats, so that they learn how to make a living without having to resort to crime. Shows and concerts are also organised inside the theatre and in community centres and parks across the city. Following the first

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concerts inside the theatre, it became clear that the acoustics were insufficient for proper communication between the acrobats and for live music performances.

The founders of Sarakasi Trust, Rudy and Marion van Dijck, got in touch with the Eindhoven University of Technology via Studium Generale, its cultural organisation. Acoustical researchers and consultants Constant Hak and Remy Wenmaekers of the university's Laboratorium voor Akoestiek (Faculty of Architecture, Building and Planning, Building Physics and Systems Unit) and Level Acoustics were willing to work together to improve the acoustics of the theatre.

Fig. 2
Reverberation and speech intelligibility measurement setup

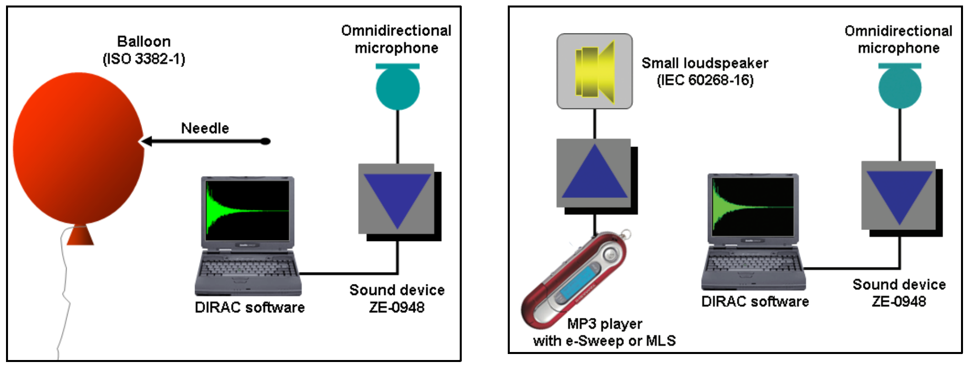


Fig. 3
Measuring reverberation time using balloons as impulsive sound sources

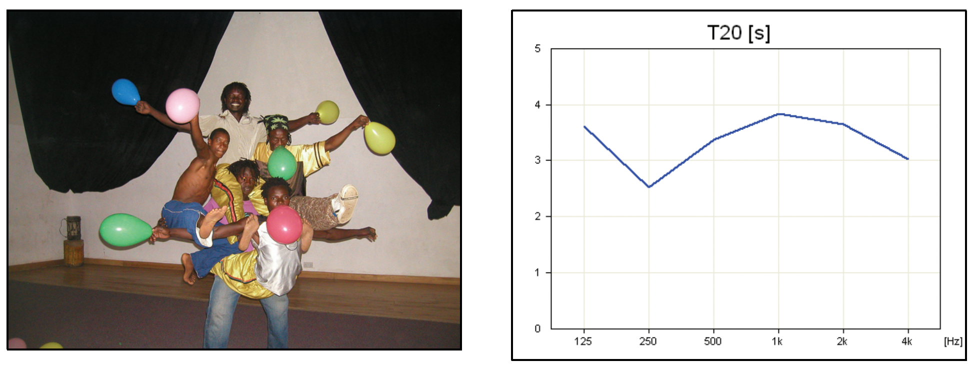
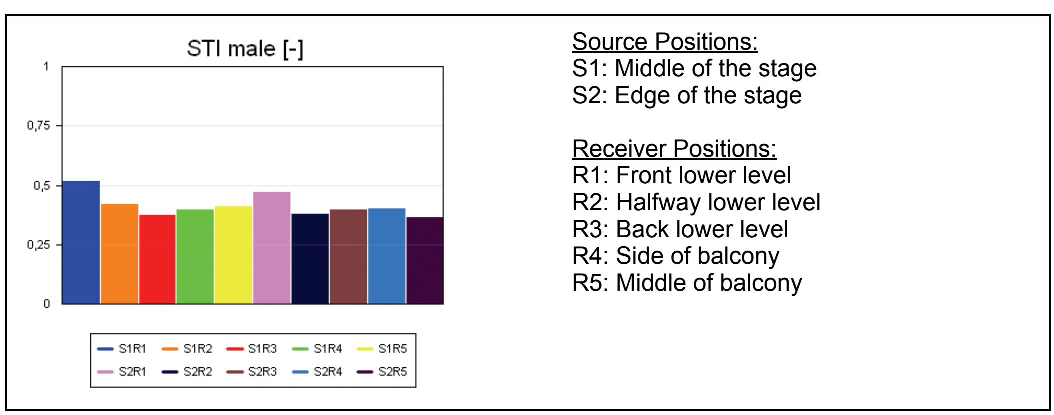


Fig. 4
Measured Speech Intelligibility values using a small loudspeaker sound source



Sound Absorption Measurements

Fig. 5
Wooden panels as sound absorption

In the theatre, 6 mm multiplex panels on a 25 mm cavity filled with low-density foam were used as low-frequency, sound absorption material. The absorption of these types of materials relies on the resonance of the panel at a typical frequency. The absorption coefficients of the 400 m² wooden panels had to be estimated for the ODEON prediction model. The resonance frequency was determined by recording the sound when tapping on the panels using DIRAC external input and a microphone. From the recording, the resonance frequency of the panels could be determined from a clear peak in the FFT spectrum graph. The resonance frequency of the wooden panels seemed to lie in the 250 Hz octave band (theoretically 200 Hz). This explains the shape of the reverberation time curve which has a dip at the 250 Hz octave band.

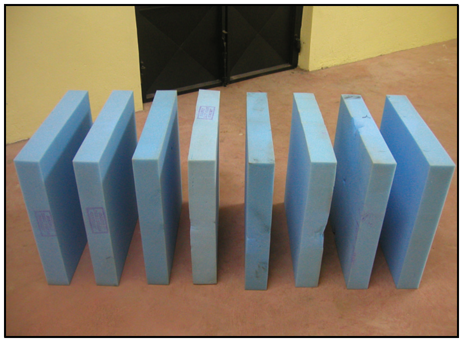


Fig. 6
Cushions used as sound absorbing baffles

Promising sound absorbing materials were gathered at the nearby market in the slums. These are the only materials directly available to the theatre. One of these materials is a low-density foam that is used for cushions and mattresses. The cushions could be used as baffles and the mattresses could be put against walls and ceiling.

The sound absorption of the cushions has been tested in an improvised laboratory setup in an empty reverberant room inside the theatre. The baffles proved to be sound absorbing up to 100% for frequencies from 125 to 4000 Hz. The mattresses proved to be sound absorbing comparable to mineral wool of the same thickness.

Room Acoustical Predictions

To be able to predict the effect of adding sound absorbing materials to the theatre, room acoustical modelling software ODEON was used. A geometric model was made from drawings during the flight from Amsterdam to Nairobi. Upon arrival, some dimensions were checked and overseen details were added. The theatre floor plan is symmetrical which makes it possible to only model half of the room and mirror the surfaces along the x-axis.

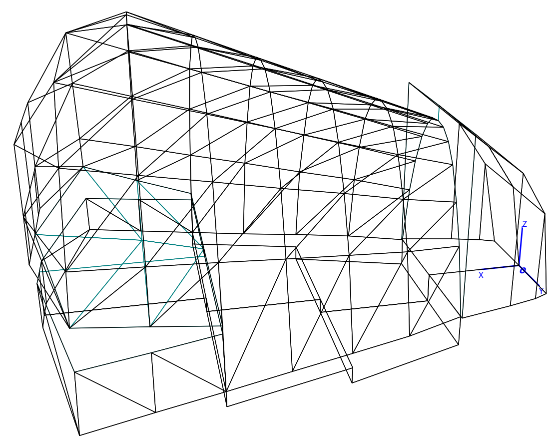


Fig. 7
Geometric model of the theatre

The same sound source and receiver positions were added to the model as used earlier during the measurements. Also, the estimated material properties of the wooden panels and curtains were added to the sound absorption database and the materials were assigned to the surfaces of the model.

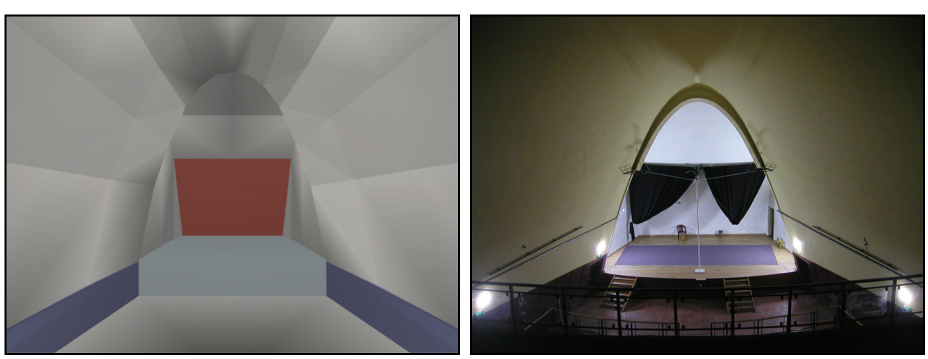
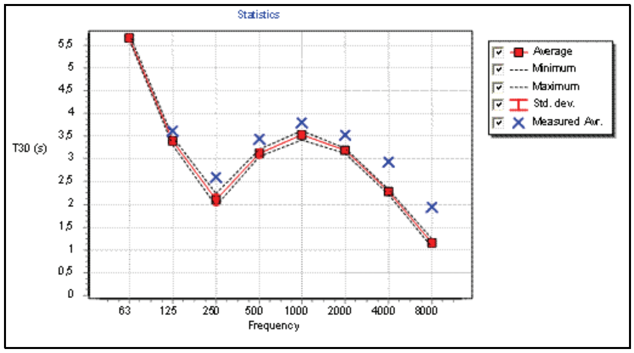


Fig. 8
Left: 3D view inside the model; Right: Photograph taken at same position

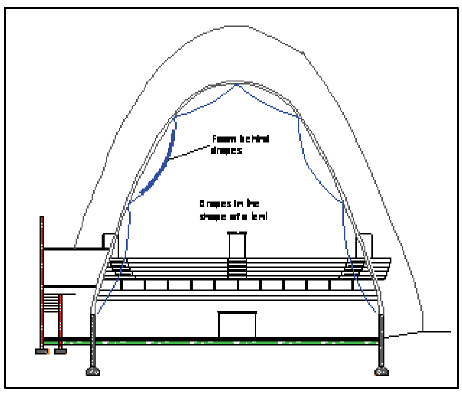
Fig. 9
Comparison of measured and simulated reverberation time inside ODEON



The room acoustical measurements have been used to calibrate the computer model, with an estimated room volume of 6000 m³. The measurement could easily be transferred from DIRAC to ODEON using the export function. This makes it possible to compare the measured and predicted room acoustical parameters such as the reverberation time without the use of Excel or other spreadsheet programs. Some of the estimated material properties were adapted to calibrate the model of the untreated room by comparison of the measured and predicted parameters (see Fig. 9).

The Acoustic Design

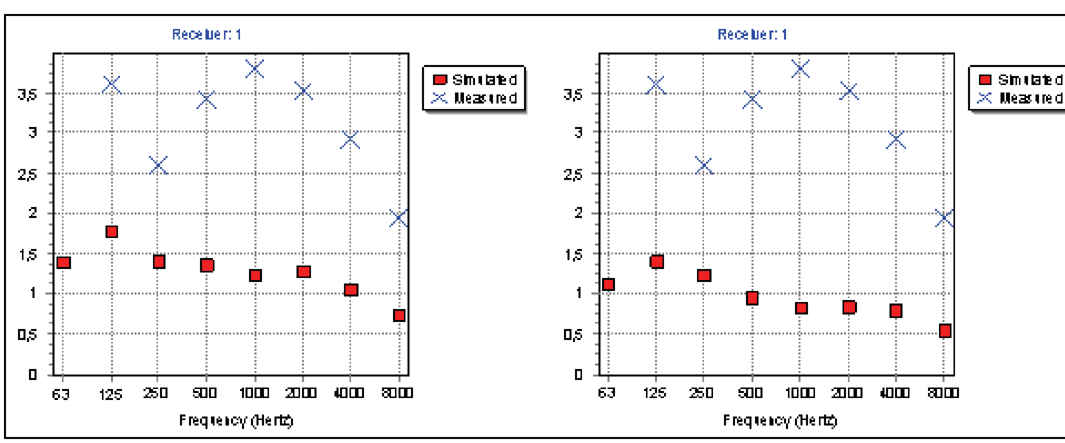
Fig. 10
Sound absorbing tent on the ceiling



The goal for the acoustic design is to achieve at least a reverberation time reduction from 3.5 to 1.5 seconds for an empty theatre, which is acceptable for rehearsing. Because there are no seats in the theatre to compensate for audience sound absorption, the reverberation time will be down to 1.0 seconds in a situation with audience, which is ideal during performances. With the use of the measurement results and the calibrated computer model, available materials were proposed for the theatre. To better absorb the low frequencies, the current wooden panels have to be modified. This can be done by enlarging the cavity of half of the panels from 25 to 100 mm and closing the panel's edges. To effectively absorb mid and high frequencies, a total of 700 m² of cloth has to be added to the theatre walls and ceiling. 300 m² of heavy curtain 150% draped have to be hung in front of 200 m² of the theatre back wall, below and above the balcony. The other 400 m² of cloth has to be draped in a double layered curtain on 200 m² of the ceiling like a tent structure (see Fig. 10). And 50 mm of foam has to be put in between the double layered curtain.

As a result, the predicted reverberation time T30 is 1.4 seconds without audience and 0.9 seconds with audience (see Fig. 11). The predicted speech intelligibility STI is 0.53 (Fair) without audience and 0.65 (Good) with audience.

Fig. 11
Predicted reverberation time after treatment, compared to the current situation. Left: Situation without audience; Right: Situation with audience



Also, recommendations were made to improve the sound insulation to reduce the background noise level from 48 dB(A) to an acceptable level of 35 dB(A). To achieve this, sound insulating doors are to be installed into the entrances from the theatre towards the foyer and all ventilation openings are to made sound lock by introducing a labyrinth of foam.

Even the acoustics of the bar has been treated, which probably makes it the first bar in Nairobi with excellent acoustics! Wrapped foam bags were proposed to be put against the bar's ceiling to reduce the reverberation time from 3.0 to below 1.0 seconds. Unfortunately, the background noise will always be high during opening hours – up to 60 dB(A) – because the front doors to the crowded Ngara Road are always open in the hot climate.

Final Result

The acoustic treatment was done just in time for the Sawa Sawa festival from 30 May to 1 June 2009, when the new theatre was opened with dance, acrobatics and music. The response from Sarakasi to the new acoustics is very good, and, if the customer is happy, the result often remains unmeasured. Unless one of our students happens to be in the neighbourhood, or some sponsor can send us again to this amazing country, we will never know. To be continued, hopefully.

Links

Building Physics and Systems: http://sts.bwk.tue.nl/bps

Level Acoustics: http://www.levelacoustics.nl

Sarakasi Trust: http://www.sarakasi.org

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